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CONTROL OF CORROSIVE WEAR IN GRINDING BALLS DURING WET GRINDING OF HEMATITE ORE

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CONTROL OF CORROSIVE WEAR IN GRINDING BALLS DURING WET GRINDING OF HEMATITE ORE

by

A.W. Lui, V.S. Sastri and J. McGoey

ABSTRACT

Reduction of wear loss of steel balls during wet grinding of hematite ore was achieved by the use of corrosion inhibitors. Highest reduction rate was obtained with inhibitors that were effectively combined. A binary component system consisting of $Na_2SiO_3 \cdot 9\ H_2O$ and $NaNO_2$ was developed and was found to perform well with an average wear reduction of 39% in 30 min grinding. Moreover, its use in the mill produced no adverse effect on grinding rate and pelletizing.

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CONTRÔLE DE LA CORROSION PAR USURE SUR DES BOULETS D'ACIER DURANT LE BROYAGE HUMIDE SUR UN MINERAI HÉMATITE

par

A.W. Lui, V.S. Sastri et J. McGoey

RÉSUMÉ

Une réduction de la perte par usure des boulets d'acier durant le broyage humide du minerai hématite a été atteinte par l'utilisation d'inhibiteurs de corrosion. Le taux de réduction le plus élevé a été obtenu par la combination d'inhibiteurs. Un système de composés binaires consistant de $Na_2SiO_3 \cdot 9\ H_2O$ et $NaNO_2$ a été développé et a bien performé avec une moyenne de réduction de l'usure de 39% après une periode de broyage de 30 minutes. De plus, son utilisation ne produit aucun effect nêgatif sur le taux de broyage et de mise en boulette.

INTRODUCTION

In ore-grinding operations, there is a considerable amount of wear loss from the steel balls. With the present trend towards lower-grade ore requiring, finer grinds for liberation of precious constituents, the grinding ball consumption per ton of concentrate recovered is very expensive. Reduction of ball wear can minimize the overall cost of the ore-processing operation.

Our earlier work (1-3) showed that ball wear can be reduced by the use of a single-component corrosion inhibitor system, without any adverse effect on the grinding rate. It was reported in the literature (4-6) that inhibition efficiency was enhanced when inhibitors were effectively combined. In this work, an attempt was made to develop a system of corrosion inhibitors so that their synergistic inhibition effect further reduces ball wear.

EXPERIMENTAL

The laboratory ball mill consisted of a single-tier roller-type mill and a porcelain jar (5.3 L capacity) rotating at a constant speed of 63 rpm. The grinding balls were supplied by Slater Industries and had the composition shown in Table 1. During grinding, a charge of 9 kg was used. The ore slurry consisted of 1150 g of hematite in 770 mL of synthetic mill water. The hematite ore was obtained from the Iron Ore Company of Canada and had a size distribution shown in Table 2. The mill water contained 2.0 g/L $SO_4^{=}$ as Na_2SO_4 and 0.5 g/L Cl^- as NaCl.

The experimental procedure was similar to that outlined in a previous report (7). During grinding, 15 marked balls were used to represent the charge of 155 balls. The average wear loss during 30 min grinding was obtained by weighing the marked balls before and after the grinding experiment. The cleaning procedure for the weight-loss measurements consisted of removing the slurry from the balls by washing with water, ultrasonic cleaning in 0.1 M Na_2CO_3 solution, rinsing again with distilled water, then alcohol, and finally drying with forced air.

The concentration of dissolved oxygen in the slurry was measured by means of an oxygen meter. The grinding efficiency of ore was determined by wet sieve analysis of ground ore. The increase in the amount of 0.074 mm particle size (-200 mesh) ore was used as a measure of grinding efficiency.

RESULTS AND DISCUSSION

In a 30 min wet grinding of hematite ore, the reduction of ball wear by the addition of inhibitors is shown in Table 3 for single-component systems and in Table 4 for binary-component systems. In Table 4, the first group of inhibitors is based on $NaNO_2$ + Na_2 (X) O_4 combinations (where X represents Cr, Mo, etc.) the second group of inhibitors is based on $Na_2SiO_3 \cdot 9\ H_2O$ +

an oxidizing inhibitor (such as Na_2CrO_4, Na_2MoO_4, etc.). The results show that the inhibition efficiency of the first combination is similar to that of the individual components. The efficiency of the second combination is, however, significantly better than that of the single component. Because of economical and ecological considerations, the binary system containing $Na_2SiO_3 \cdot 9 H_2O$ and $NaNO_2$ which produced an inhibition efficiency of 39% was selected for further study. The results are shown in Table 5 and Fig. 1. In general, the wear reduction increased as the concentration of inhibitor increased, but there is a limiting concentration beyond which the inhibition efficiency decreased. Figure 1 shows the optimum ratio of $Na_2SiO_3 \cdot 9 H_2O$ to $NaNO_2$ to achieve a maximum reduction in wear.

The efficiency of the binary system was also investigated when the grinding time was extended. The results are shown in Table 5. With 90 min grinding time, the inhibition efficiency reached a maximum of 33% compared with 39% for the 30 min run. At the end of 90 min grinding, the concentration of dissolved oxygen in the ore-slurry solution as measured by an oxygen meter was 4.6 ppm compared with 5.5 ppm for a 30 min run. $Na_2SiO_3 \cdot 9 H_2O$ is not an oxidizing agent, but it does require dissolved oxygen to function as an inhibitor. It appears that a lower dissolved oxygen concentration lowers its inhibition ability. Other factors, such as depletion of inhibitors at longer grinding times, a lower abrasion component in the total wear with finer grinds at longer time could also play a role in the change of wear reduction rate.

The binary ($Na_2SiO_3 \cdot 9 H_2O + NaNO_2$) system has been shown to be effective in reducing ball wear. It is important to know the effect of adding inhibitors on the grinding rate. Wet screen analysis on ground ore was carried out when grinding was done with and without the addition of the inhibitor. In 30 min grinding, the increase in -200 mesh ore in both cases was 42%. In 90 min grinding, the increase was 72%. Thus their addition has no effect on the grinding rate.

The addition of sodium silicate can cause an increase in Si content of the ore which might have an adverse effect on the pelletizing operation. The Si contents were determined for ore as received and for ore treated with inhibitors, ground and filtered (but not washed). Results showed that the Si content increased from 2.44% to 2.81% for 0.05 M inhibitor addition and from 2.44% to 3.02% for 0.10 M inhibitor addition. The total Si content is not considered high enough to cause any problem in pelletizing.

CONCLUSIONS

1. During wet grinding of hematite ore in a synthetic mill water containing 2.0 g/L $SO_4^=$ and 0.5 g/L Cl^-, the amount of ball wear in a 30 min run was 0.78 mg/mm^2.

2. Ball wear can be reduced by the use of inhibitor ranging from 11 to 31% for single inhibitor system and from 24 to 40% for binary inhibitor system.

3. The reduction of ball wear increases as the concentration of inhibitor increases, but there is a limiting concentration beyond which ball wear reduction decreases.

4. Inhibition efficiency was enhanced when inhibitors were effectively combined. $Na_2SiO_3 \cdot 9\ H_2O$ was found to synergise well with an oxidizing inhibitor. A blend based on $Na_2SiO_3 \cdot 9\ H_2O$ and $NaNO_2$ has been shown to be effective in reducing ball wear.

5. Use of the inhibitors in hematite ore grinding has no effect on the grinding rate as indicated by the measure of -200 mesh ore after grinding.

6. Use of the ($Na_2SiO_3 \cdot 9\ H_2O + NaNO_2$) system in hematite ore grinding increased the Si-content marginally and had no effect on the pelletizing process.

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Table 1. Composition of steel ball (element %)

C	Si	Mn	S	Cr	Ni	Cn
0.64	0.22	0.34	0.02	0.41	0.05	0.23

Table 2. Screen analysis of hematite ore (wt %)

Mesh Size	wt %
+ 80	93.4
+80 + 100	3.1
-100 + 150	2.0
-150 + 200	1.1
-200	0.4

Table 3. Reduction of ball wear by single inhibitor system in 30 min grinding

Inhibitor	Concentration (m/L)	% Reduction
HEDP*	0.01	11
HEDP*	0.05	13
Na_2CrO_4	0.05	30
Na_2CrO_4	0.10	31
Na_2MoO_4 2 H_2O	0.05	25
Na_2MoO_4 2 H_2O	0.10	27
Na_2WO_4 2 H_2O	0.05	25
Na_2WO_4 2 H_2O	0.10	26
$NaNO_2$	0.05	25
$NaNO_2$	0.10	27
Na_2SiO_3 9 H_2O	0.05	29
Na_2SiO_3 9 H_2O	0.10	28
no inhibitor: wear loss = 0.78 mg/mm^2		

* Hydroxyethylidene diphosphonic acid

Table 4. Reduction of ball wear by binary inhibitor system in 30 min grinding.

Inhibitors	% Reduction
0.05 M $NaNO_2$ + 0.05 M Na_2CrO_4	29
0.10 M $NaNO_2$ + 0.10 M Na_2CrO_4	29
0.05 M $NaNO_2$ + 0.05 M Na_2MoO_4 2 H_2O	24
0.10 M $NaNO_2$ + 0.10 M Na_2MoO_4 2 H_2O	24.5
0.05 M $NaNO_2$ + 0.05 M Na_2WO_4 2 H_2O	25
0.10 M $NaNO_2$ + 0.10 M Na_2WO_4 2 H_2O	26
0.05 M Na_2SiO_3 9 H_2O+ 0.05 M Na_2CrO_4	39
0.10 M Na_2SiO_3 9 H_2O + 0.10 M Na_2CrO_4	40
0.05 M Na_2SiO_3 9 H_2O + 0.05 M Na_2WO_4 2 H_2O	38
0.10 M Na_{SiO3} 9 H_2O + 0.10 M Na_2WO_4 2 H_2O	39
0.05 M Na_2SiO_3 9 H_2O + 0.05 M Na_2MoO_4 2 H_2O	38
0.10 M Na_2SiO_3 9 H_2O + 0.10 M Na_2MoO_4 2 H_2O	38
0.05 M Na_2SiO_3 9 H_2O + 0.05 M $NaNO_2$	39
0.10 M Na_2SiO_3 9 H_2O + 0.10 M $NaNO_2$	39

Table 5. Reduction of ball wear by Na_2SiO_3 9 H_2O and $NaNO_2$

[Na_2SiO_3 9 H_2O] m/L	[$NaNO_2$] m/L	Grinding time min	Reduction %
0.001	--	30	19
0.005	--	30	27
0.010	--	30	29
0.050	--	30	29
0.100	--	30	28
--	0.01	30	12
--	0.05	30	25
--	0.10	30	27
0.01	0.01	30	30
0.05	0.05	30	39
0.10	0.10	30	39
0.20	0.20	30	27
0.05	0.025	30	33
0.05	0.05	30	39
0.05	0.10	30	39
0.05	0.15	30	39
0.05	0.20	30	39
0.025	0.05	30	32
0.05	0.05	30	39
0.10	0.05	30	39
0.15	0.05	30	39
0.05	0.05	90	29
0.10	0.10	90	33
0.15	0.15	90	33

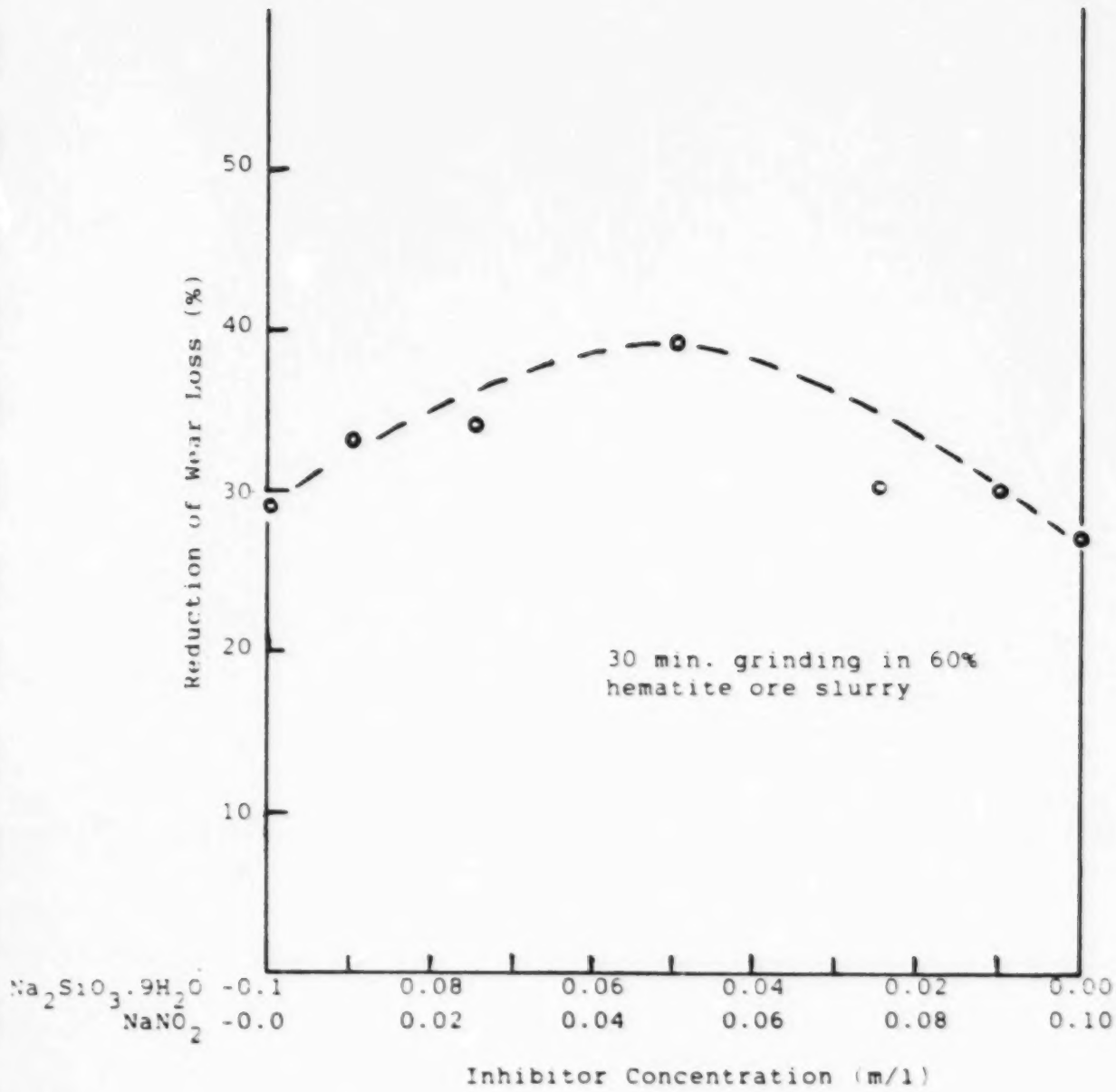

Fig. 1. Optimum ratio of $Na_2SiO_3 \cdot 9\ H_2O$ and $NaNO_2$ in the binary system to reduce wear.